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Transporting Isowean Pigs—Part II: Responses to Potential In-transit Thermal Conditions

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Abstract

The goal of this research was to explore the feasibility and protocols to transport isowean pigs long distance. This study was the second part of the effort that examined the thermal environment aspects of such a practice. Isowean pigs of PIC genetics (10 to 12 days old) were subjected to simulated 54-h in-transit temperature pattern of 80 ± 0, 5, 10 or 15°F. The pigs were provided with water supplement (average dosage of 2 lb/pig) during the treatment period and ad libitum feeding during a 14-d growth period. All pigs had similar weight loss (8.4 to 8.9% of their initial body weight) during the treatment period. The only difference in total weight gain during the growth period was between pigs previously exposed to 80 ± 15°F (8.33 lb) and those previously exposed to 80 ± 10°F (9.15 lb) (P0.05). All pigs showed similar physiological and energetic responses during both treatment and growth periods. The treatment period led to elevated concentrations of hematocrit, plasma protein, blood urea nitrogen, sodium and chloride, but declined glucose level (P

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Summary and Implications

The goal of this research was to explore the feasibility and protocols to transport isowean pigs long distance. This study was the second part of the effort that examined the thermal environment aspects of such a practice. Isowean pigs of PIC genetics (10 to 12 days old) were subjected to simulated 54-h in-transit temperature pattern of 80 ± 0, 5, 10 or 15°F. The pigs were provided with water supplement (average dosage of 2 lb/pig) during the treatment period and *ad libitum* feeding during a 14-d growth period. All pigs had similar weight loss (8.4 to 8.9% of their initial body weight) during the treatment period. The only difference in total weight gain during the growth period was between pigs previously exposed to 80 ± 15°F (8.33 lb) and those previously exposed to 80 ± 10°F (9.15 lb) ($P<0.05$). There was no significant difference in feed conversion among the regimens ($P>0.05$). All pigs showed similar physiological and energetic responses during both treatment and growth periods. The treatment period led to elevated concentrations of hematocrit, plasma protein, blood urea nitrogen, sodium and chloride, but declined glucose level ($P<0.05$). The blood constituents returned to normal levels during the growth period. The results suggest that the isowean pigs were able to cope well with air temperature fluctuations of up to ±15°F around the thermoneutral condition of 80°F air temperature with floor bedding.

Introduction

Previous study conducted in our laboratory revealed that isowean pigs responded well to post-weaning nutritional conditions that may be encountered during extended overseas shipment journeys (15). In-transit supply of water replacement could be beneficial in alleviating dehydration of the animals. The study was conducted at constant thermoneutral (TN) condition of 80°F air temperature with floor bedding to avoid possible interference of thermal factors with the nutritional regimens. Having investigated the effects of the nutritional regimens on the ability of the pigs to cope with the potential long journeys, the next logical step would be to quantify the effects of possible in-transit thermal conditions on this type of pigs for a selected nutritional regimen. After all, the thermal environment during overseas shipment is subject to considerable fluctuations, as has been reported by Xin and Rieger (16) for air shipment of day-old breeder chicks. These unique, in-transit thermal fluctuations seldom occur in typical production facilities for young animals. Literature reports on the effects of fluctuating temperatures on pigs all dealt with pigs older than 4 weeks of age (1, 2, 4, 5, 6, 7, 8, 9, 11, 12, 17). Since an animal's ability of thermoregulation largely depends upon its age, directly referring to the literature data for this unique situation may lead to erroneous conclusions. Moreover, the magnitude and temporal patterns of the thermal fluctuations examined in this study differ considerably from those examined in the literature reports. The objective of this study was to quantify the effects of simulated in-transit fluctuating temperatures on isowean pigs.

Materials and Methods

Temperature regimens and isowean pigs

Four temperature regimens were examined in this study, including a constant temperature of 80°F, and three cyclic temperatures of 80±5°F (mean of 79°F), 80±10°F (mean of 79°F) and 80±5°F (mean of 78°F) (fig. 1). Relative humidity (RH) at 80°F averaged 35% (± 3%) and was allowed to vary as temperature cycled. Air draft at the pig level was less than 30 ft/min.

Three trials were conducted. Each trial involved 60 isowean barrows (10 to 12 days of age, PIC genetics) that were transported by nursery truck from a PIC breeder farm in Minnesota to the LEAP Research Laboratory of Iowa State University, Ames, Iowa. Upon arrival, the pigs were individually weighed and randomly assigned to four environment-controlled indirect calorimeter chambers, 15 pigs per chamber. The average initial body weight was relatively equalized

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among the chambers. Each chamber had a specific temperature regimen that lasted for 54 h (including the ground transport time of 6.5 to 7 h). During the treatment period, each chamber was provided with 30 lb Aqua-Jel® (AJ) water replacement that was placed in a wooden trough along a sidewall of the chamber. The same bedding as used in our previous study (15) was used. A wooden platform for accessing the AJ supply was used to minimize the bedding materials from being mixed into the AJ. Darkness was used during the treatment period except that a 15-Watt red light was used for visual observation of the pigs. Following the treatment period was a 14-d subsequent growth period. The same procedures and management practices as used in our previous study (15) were followed.

Response variables

The same response variables as described in the previous study (15) were used to determine the treatment effects. They included individual body weight (BW) at onset of the treatment, at end of the treatment, and at end of the first and second week of growth period; hematological and chemical parameters of the blood, including hematocrit, plasma protein, blood urea nitrogen (BUN), glucose, and Na^+, K^+, Cl^-, and HCO_2^- contents; weekly feed intake and feed conversion (FC) during the growth period; energetic responses (THP, MP, SHP, and RQ); and mortality and morbidity. In addition, postural behaviors of the pigs during the treatment period were recorded at 1-h intervals with programmable cameras. The response variables were subjected to analysis of variance and multiple means comparisons following an arrangement of complete randomized block design.

Results and Discussion

Treatment effects on BW and FC

BW at different stages of the trial, BW gain or loss, and FC of the pigs are summarized in Table 1. Pigs in all the temperature regimens had the similar BW loss of 0.75 to 0.79 lb/pig or 8.4 to 8.9% of the initial BW (IBW) during the treatment period. BW gain during the first week of growth was also similar, averaging between 3.15 to 3.33 lb/pig or 39 to 41% of the weekly beginning BW (WBBW). Differences in BW gain were noticed during the second week of growth. Pigs previously exposed to the 80°C or 80 ± 10°F regimen showed higher BW gain (5.82 lb/wk; 51~52% WBBW) than pigs previously exposed to 80 ± 5°F or 80 ± 15°F regimen (5.07 to 5.38 lb/wk; 45~47% WBBW) ($P<0.05$). Overall, pigs previously exposed to 80±15°F showed slower gain (8.33 lb; 103% IBW) than those previously exposed to 80 ± 10°F (9.15 lb; 113% IBW) ($P<0.05$). However, there was no significant differences in overall BW gain among the regimens of 80°F, 80 ± 5°F and 80 ± 15°F or among 80°F, 80 ± 5°F and 80 ± 10°F ($P>0.05$). There were also no significant differences in FC among the regimens for the first week of growth or for the total 14-d growth period ($P>0.05$). Difference in FC was detected between 80°F and 80 ± 5°F (1.11 vs. 1.26) during the second-week growth. BW gain and FC in the present study were similar to those found in our previous study (15).

Treatment effects on physiological responses

The results of blood analyses for various experimental stages are summarized in Table 2. There were no significant treatment effects on any of the response variables ($P>0.05$) during both the treatment period and the growth period. However, exposure to the treatment duration (54 hr) led to elevated concentrations of hematocrit, plasma protein, BUN, sodium, and chloride ($P<0.05$), but declined glucose concentration ($P<0.05$). Concentrations of potassium and bicarbonate remained relatively constant ($P>0.05$). The somewhat elevated hematocrit, sodium, and chloride concentrations during the treatment period were presumably an effect of dehydration. The marked increase in BUN concentration is an indication that the pigs were degrading protein to supply energy to meet their energy needs and offset the decline in glucose concentration. The glucose content measured in the current study (104 mg/dl) was considerably higher than the generally recognized hypoglycemic level of 75 mg/dl (14). The blood concentrations returned to normal levels during the growth period. These results were consistent with those of our previous study (15).

Treatment effects on bioenergetics

The average THP (W/kg), MP (g/kg-h), SHP (W/kg), and RQ (VCO_2/VO_2) of the pigs for the treatment and growth periods are shown in Table 3. As found with the physiological responses, there were no significant treatment effects on any of the energetic responses ($P>0.05$) during both the treatment and the subsequent growth period. The lower THP during the treatment period presumably resulted from the absence of external energy supply and a relatively undeveloped metabolic system of the pigs. Results of the isowean pig energetics obtained from the current study compared favorably with those obtained in our previous study (15). The dynamic responses of THP and SHP to the temperature variation are illustrated in Figures 2 and 3 for pigs exposed to the 80 ± 15°C regimen. It can be seen that THP was positively related to air temperature whereas SHP was negatively related to air temperature. Note that SHP of the present study took into account the amount of sensible heat consumed in evaporation of the water supply–AJ, consequently, it was deemed to be lower than the sensible heat loss by the pigs. This explains the occasional negative values of SHP where supplemental heat was used in evaporating water or water-laden substances. However, SHP obtained as such more truly reflects the practical situation, thereby providing more realistic data for ventilation design of shipment facilities.

Treatment effects on behavioral responses

A series of representative images depicting postural patterns of the pigs at selected temperature moments of the exposure period are shown in Figure 4. Pigs generally take the posture of nearly touching one another on the side when comfortable, huddling when cold, and spreading out when too warm or hot (10). Using these behavioral criteria on thermal comfort, it can be seen that with the bedded flooring of the present study, air temperatures of 75 to 84°F seem to be within the thermal neutral zone of these pigs. Air temperatures of 70°F or lower would be cool or cold, whereas air temperatures of 90°F or higher would be too warm. However, the physiological, energetic and performance responses of the pigs show that the pigs coped well with the intensity (i.e., magnitude and duration) of the thermal fluctuations. The huddling behavior was assumed to contribute to the reduced THP at the lower air temperatures (Figure 2). The availability of the AJ also was speculated to help reducing the potential adverse effects of the high temperature episodes.

Belly nosing (BN) behavior

The same BN behavior as observed in our previous study (15) existed in the current study. As previously observed, this behavior generally started within two days of the growth period. The intensity of BN behavior tended to increase with time initially and then gradually diminished. There was no clear indication that BN was treatment specific. The behavior did not seem to adversely affect performance of the pigs, which agreed with the report by Borgman et al. (3).

Mortality and morbidity

There was no mortality for all the trials. One morbid pig in the 80 ± 5°F regimen (trial #1, initial BW of 6.3 lb) and two morbid pigs in the 80 ± 15°F regimen (trials 1 and 3) were culled during the first-week growth period. Diagnosis by the ISU Veterinary Diagnostic Laboratory revealed that the two pigs from trial 1 had moderate bacterial pneumonia and the pig from trial 3 had septicemia due to *Streptococcus equisimilis*.

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Table 1. Body weight (BW) and feed conversion (FC) of isowean pigs (PIC breed) during and subsequent to simulated in-transit air temperature regimens. The pigs were provided with Aqua-Jel® water replacement during treatment period and fed ad-lib during growth period. Ambient temperature was 28.9°C and 27.8°C, respectively, during the first and second week of growth.

Period	54h Temp.	BW, lb.		BW Gain, lb.				FC (Feed/Gain)	
	Regimen	Mean	S.D.	Mean	S.D.	Pct	S.D.	Mean	S.D.
Initial	80°F	8.87	1.03						
	80 ± 5°F	8.87	1.21						
	80 ± 10°F	8.84	1.14						
	80 ± 15°F	8.87	1.19						
54 h (Treatment)	80°F	8.10	1.03	-0.75	-0.24	-8.6%	-2.9%		
	80 ± 5°F	8.12	1.14	-0.75	-0.20	-8.4%	-2.2%		
	80 ± 10°F	8.07	1.03	-0.77	-0.24	-8.7%	-2.9%		
	80 ± 15°F	8.07	1.14	-0.79	-0.20	-8.9%	-2.3%		
1st week (Growth)	80°F	11.24	1.50	3.15	0.79	39%	9%	0.91	0.12
	80 ± 5°F	11.42	1.63	3.26	0.95	40%	10%	0.91	0.02
	80 ± 10°F	11.40	1.58	3.32	0.95	41%	11%	0.84	0.05
	80 ± 15°F	11.33	1.78	3.26	0.81	41%	9%	0.87	0.04
2nd week (Growth)	80°F	17.07	2.27	5.81^{a}	0.97	$52\%^{a}$	6%	1.11^{a}	0.08
	80 ± 5°F	16.81	2.38	5.37^{b}	1.03	$47\%^{b}$	8%	1.26^{b}	0.03
	80 ± 10°F	17.25	2.66	5.81^{a}	1.39	$51\%^{a}$	11%	$1.18^{a,b}$	0.07
	80 ± 15°F	16.39	2.64	5.06^{b}	1.19	$45\%^{b}$	8%	$1.22^{a,b}$	0.07
Overall	80°F			$8.95^{a,b}$	1.58	$111\%^{a,b}$	18%	1.02	0.07
	80 ± 5°F			$8.62^{a,b}$	1.80	$107\%^{a,b}$	22%	1.10	0.03
	80 ± 10°F			9.13^{a}	1.96	$113\%^{a}$	22%	1.05	0.06
	80 ± 15°F			8.32^{b}	1.83	$103\%^{b}$	19%	1.08	0.02

For the specific treatment or growth period, column means with different superscript letters were significantly different ($P<0.05$); unlabeled means were not significantly different ($P>0.05$).

Table 2. Blood parameters of isowean pigs (PIC breed) during and subsequent to simulated in-transit air temperature regimens.

Serological Response Variable	54h Temp. Regimen	Initial Mean	Initial S.D.	54 h Mean	54 h S.D.	2nd week Mean	2nd week S.D.
Hematocrit, %	80°F	34.7	1.6	38.9	1.6	31.9	2.0
	80 ± 5°F	33.7	2.6	38.1	2.3	33.5	2.3
	80 ± 10°F	34.7	2.2	38.7	1.6	32.9	2.2
	80 ± 15°F	33.7	2.3	38.4	2.5	31.6	4.4
	Overall	**34.2^{y}**	**2.2**	**38.5^{x}**	**2.0**	**32.5^{z}**	**2.7**
Plasma protein, gm/dl	80°F	6.3	0.5	7.0	0.7	5.1	0.3
	80 ± 5°F	6.3	0.2	6.9	0.3	5.1	0.3
	80 ± 10°F	6.3	0.4	7.0	0.5	5.3	0.4
	80 ± 15°F	6.2	0.6	7.1	0.6	5.1	0.4
	Overall	**6.3^{y}**	**0.4**	**7.0^{x}**	**0.5**	**5.1^{z}**	**0.4**
BUN, mg/dl	80°F	8.9	3.7	30.4	5.9	7.9	1.8
	80 ± 5°F	8.8	2.2	27.5	8.5	8.5	1.6
	80 ± 10°F	8.1	2.3	30.0	9.0	8.7	1.4
	80 ± 15°F	9.1	2.9	31.3	6.7	7.7	1.8
	Overall	**8.8^{b}**	**2.8**	**29.8^{a}**	**7.5**	**8.2^{b}**	**1.7**
Glucose, mg/dl	80°F	126.7	11.5	104.3	35.1	125.1	9.0
	80 ± 5°F	122.2	8.1	105.1	13.1	124.6	13.8
	80 ± 10°F	119.5	10.3	101.5	9.0	123.9	13.9
	80 ± 15°F	118.7	9.7	104.6	9.0	117.0	9.4
	Overall	**121.8^{x}**	**9.9**	**103.9^{y}**	**16.5**	**122.7^{x}**	**11.5**
Sodium, mEq/L	80°F	141.6	2.9	146.3	7.0	140.0	1.9
	80 ± 5°F	141.5	2.8	145.9	6.3	140.3	2.1
	80 ± 10°F	141.1	2.2	147.0	2.6	140.2	1.8
	80 ± 15°F	141.2	2.5	146.9	4.1	140.3	1.4
	Overall	**141.3^{y}**	**2.6**	**146.5^{x}**	**5.0**	**140.2^{y}**	**1.8**
Potassium, mEq/L	80°F	5.1	0.6	5.0	0.6	5.5	0.6
	80 ± 5°F	4.9	0.4	4.9	0.3	5.6	0.6
	80 ± 10°F	4.9	0.5	5.1	0.5	5.7	0.6
	80 ± 15°F	5.1	0.6	5.1	0.5	5.8	0.5
	Overall	**5.0^{y}**	**0.5**	**5.0^{y}**	**0.5**	**5.7^{x}**	**0.6**
Chloride, mEq/L	80°F	105.2	2.5	107.9	6.1	100.8	2.8
	80 ± 5°F	104.5	2.0	107.5	5.5	100.9	4.0
	80 ± 10°F	105.1	1.8	109.8	2.0	101.3	2.3
	80 ± 15°F	104.8	2.1	109.0	4.2	101.5	2.3
	Overall	**104.9^{y}**	**2.1**	**108.6^{x}**	**4.5**	**101.2^{z}**	**2.9**
Bicarbonate, mEq/L	80°F	21.0	2.1	23.2	1.9	23.6	2.3
	80 ± 5°F	22.1	1.7	21.9	2.3	24.0	1.6
	80 ± 10°F	20.6	1.6	21.1	2.2	23.5	2.1
	80 ± 15°F	21.9	1.6	21.7	3.0	24.2	1.8
	Overall	**21.4^{y}**	**1.8**	**22.0^{y}**	**2.4**	**23.8^{x}**	**2.0**

For a response variable, row means with different superscript letters were significantly different ($P<0.05$).

Table 3. Energetic responses of isowean pigs (PIC breed) during simulated in-transit air temperature regimens and subsequent growth under thermoneutrality.

Period	54h Temp	BW, kg		THP, W/kg		MP, g/h·kg		SHP, W/kg		RQ	
	Regimen	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
54 h	80°F	3.86	0.47	4.1	1.4	4.4	1.6	1.2	0.9	0.85	0.14
	80 ± 5°F	3.86	0.53	4.3	1.5	4.5	2.0	1.2	0.9	0.80	0.11
	80 ± 10°F	3.84	0.49	4.1	1.0	4.1	1.5	1.3	0.9	0.82	0.11
	80 ± 15°F	3.85	0.53	4.2	1.5	4.2	2.0	1.4	1.0	0.80	0.11
	Overall	**3.85**	**0.51**	**4.2**	**1.4**	**4.3**	**1.8**	**1.3**	**0.9**	**0.82**	**0.12**
1st week	80°F	4.40	0.57	5.1	2.0	4.0	1.6	2.3	1.0	0.91	0.13
(84°F)	80 ± 5°F	4.44	0.63	4.6	1.8	3.7	1.4	2.1	1.0	0.89	0.14
	80 ± 10°F	4.42	0.60	4.7	1.4	3.7	1.2	2.2	0.8	0.90	0.12
	80 ± 15°F	4.41	0.66	4.9	1.7	3.7	1.4	2.3	0.9	0.88	0.11
	Overall	**4.42**	**0.62**	**4.8**	**1.7**	**3.8**	**1.4**	**2.3**	**0.9**	**0.89**	**0.12**
2nd week	80°F	6.44	0.85	4.9	1.4	3.6	1.3	2.5	0.6	0.99	0.11
(82°F)	80 ± 5°F	6.41	0.91	4.9	1.6	3.7	1.3	2.4	0.9	0.97	0.13
	80 ± 10°F	6.51	0.97	4.7	0.9	3.5	1.0	2.3	0.5	0.99	0.12
	80 ± 15°F	6.30	1.01	4.7	1.3	3.4	1.3	2.4	0.7	0.98	0.11
	Overall	**6.41**	**0.93**	**4.8**	**1.3**	**3.5**	**1.2**	**2.4**	**0.7**	**0.98**	**0.12**

Conversion factor: 1 kg = 2.2 lb.

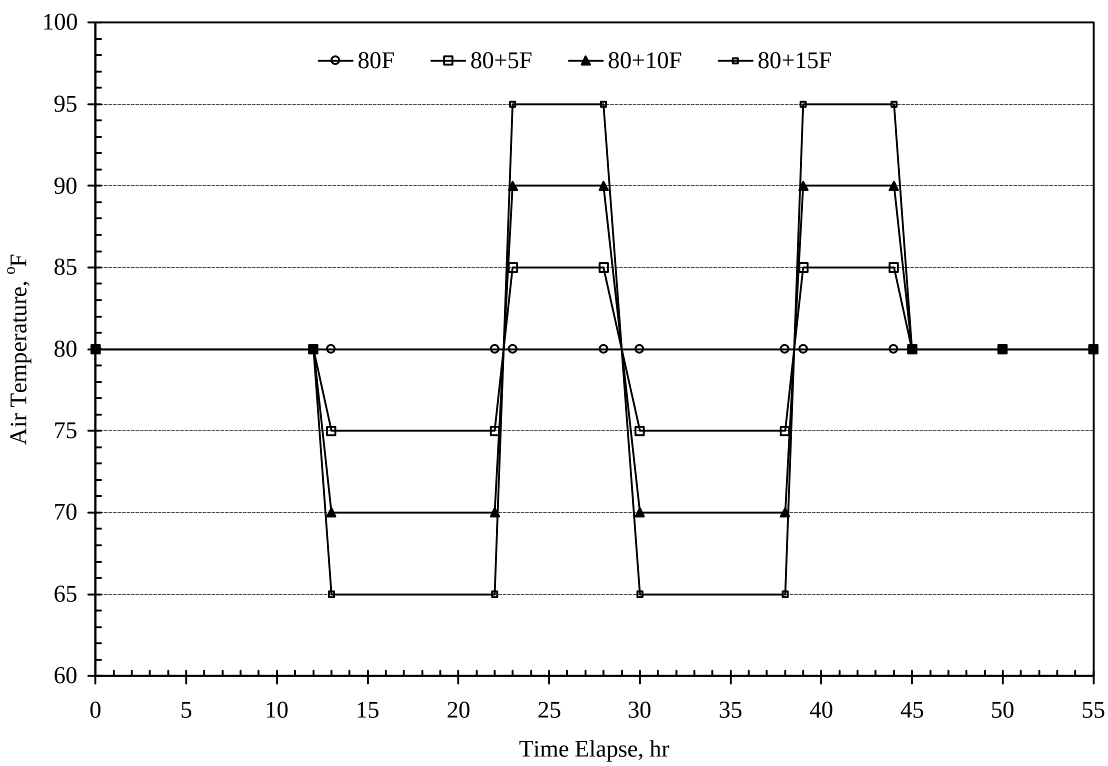


Figure 1. The theoretical experimental constant and cyclic air temperature regimens.

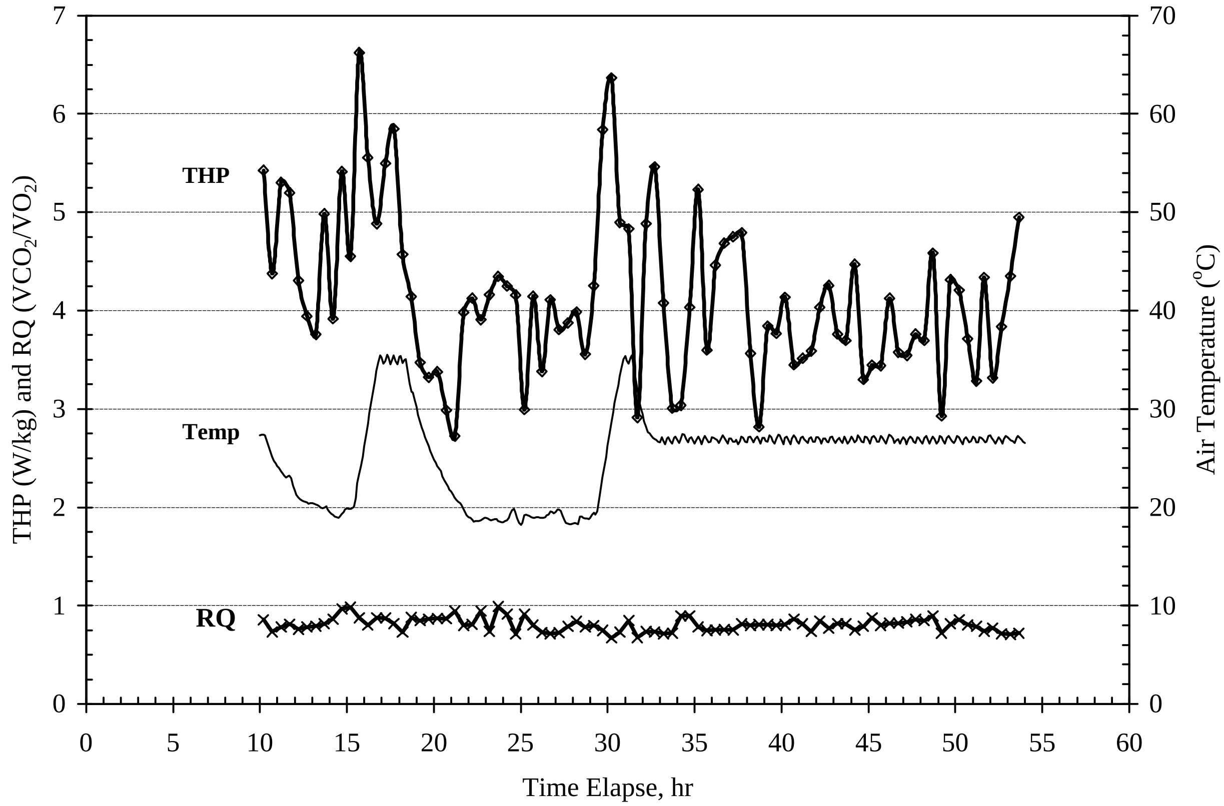


Figure 2. Dynamic total heat production (THP) and respiratory quotient (RQ) of isowean pigs exposed to 80 ± 15°F.

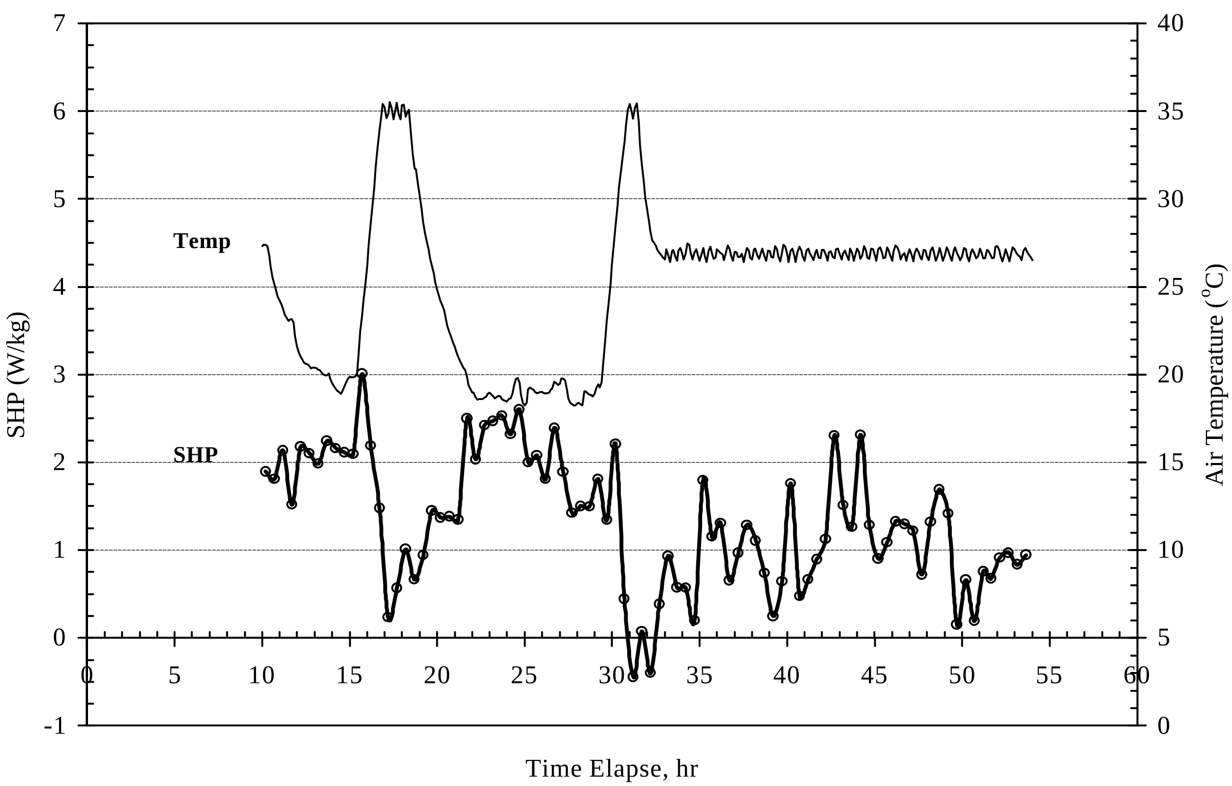


Figure 3. Dynamic sensible heat production rate (SHP) of isowean pigs exposed to 80 ± 15°F.




80F (2/15, 20h): 80 °F

80F (2/15, 22h): 80 °F

80F (2/15, 23h): 80 °F

80F (2/17, 03h): 80 °F

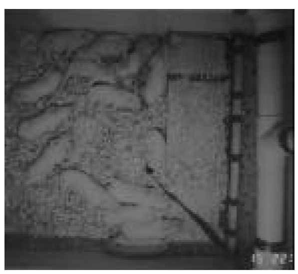
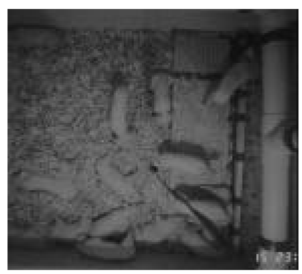



80 ±5F (2/15, 19h): 75°F

80 ±5F (2/15, 22h): 81°F

80 ±5F (2/15, 23h): 84°F

80 ±5F (2/17, 03h): 80°F


80 ±10F (2/15, 20h): 72°F

80 ±10F (2/15, 22h): 82°F

80 ±10F (2/15, 23h): 90°F

80 ±10F (2/17, 02h): 81°F




80 ±15F (2/15, 20h): 66°F

80 ±15F (2/15, 22h): 79°F

80 ±15F (2/15, 23h): 95°F

80 ±15F (2/17, 03h): 80°F

Figure 4. Postural behaviors of isowean pigs at various moments of the constant (80°F) and cyclic (80 ± 5, 10. or 15°F) temperature regimens. The exposure started at 15h on February 15, 1999.